

# Improving Network Lifetime in Wireless Sensor Network Using Fuzzy Logic Based Clustering Combined With Mobile Sink

Phan Thi The\*, Vu Nhu Manh\*\*, Tran Cong Hung\*\*, Le Dien Tam\*

\*Department of Information Technology, Thu Duc College, Ho Chi Minh 70000, Viet Nam

\*\*Department of Information Technology II, Posts & Telecommunications Institute of Technology, Ho Chi Minh 70000, Viet Nam

phanthithe@gmail.com, vunhumanh1984@gmail.com, conghung@ptithcm.edu.vn, tamld@tdc.edu.vn

**Abstract**— The issues related to energy consumption and prolonging the lifetime of wireless sensor networks (WSNs) have been studied. The deployment of a transceiver station in a WSN is a major concern. Supposing the base stations are static (fixed), however they are capable of moving in some situations to collect data from sensor nodes. In order to achieve higher energy efficiency results, the mobility of the base station to increase the lifetime of the WSN is considered in this article. We propose a strategy that combines moving sinks by fixed-path sink with fuzzy clustering algorithm that results the proposed algorithm has better performance in terms of network life, stability and packet delivery compared to Leach, Cluster Head Election mechanism using Fuzzy logic (CHEF) in performance evaluation through simulation software MATLAB

**Keywords**— Mobile Sink, Clustering, Leach, Energy-efficient Clustering, Cluster Head Election mechanism using Fuzzy logic

## I. INTRODUCTION

In recent years, Wireless Sensor Networks (WSNs) has appealed more and more researchers because of the enormous benefits that they can provide to the industrial and socio-economic fields. The major goal of WSN is to provide end-users with information gathered around the sensor area by sink, data communication (sending and receiving) [1] which is the most energy consuming activity of the nodes. And the energy consumption is proportional to the distance between the sender and receiver, ie the closer to the receiver, the lower the power consumption and vice versa. The popular way to save node energy is to organize the WSN as clusters. Each cluster is managed by the cluster head (CH) acting as the intermediary between the members in the cluster with the sink. A CH is selected among the members of the cluster mainly according to the remaining high energy level which collects perceived data from its members and sends them to the sink. Operation is concentrated in such a way that the nodes must use the minimum transmission range to save energy. In order to reduce the energy consumption of the CHs, the sink must move near the CH to collect sensible data from the CH, using a short transmission range and thus spend low energy. Therefore the problem is then to find an effective strategy of

mobile sink around the CH. Currently with the advancement in wireless technology, mobile sink or sink mobility is a hot topic and lot of work is being done in this field considering the large / multimedia type data targeting routing techniques for QoS and Network life time with goal of achieving efficient performance both in terms of routing and improved network life time. The LEACH [2] protocol is seen as a platform-based protocol; In this work, LEACH is enhanced to act as a clustering-based routing protocol with efficient fuzzy logic implementation to select better cluster head. The application of fuzzy logic in cluster selection is better than LEACH and the idea of combining the CHEF[3] fuzzy clustering algorithm with the mobile sink balances the energy consumption between the CH nodes because it can reduce the transmission range between those nodes with sink.

In this paper, there are two proposal in this paper. With the first proposal, a mobile accessory coupled with LEACH clustering routing protocols, and the second algorithm based on fuzzy logic using the CHEF algorithm with a circular sink mobility model with different radius. Simulations suggest that the second solution offers better results than the LEACH, CHEF and the first proposal, thereby improving the lifecycle of the wireless sensor network.

## II. RELATED WORKS

LEACH is one of the most famous clustering protocol. This is the first clustering approach for WSN. LEACH functions are classified into loops in which each loop begins with the set phase that performs the clustering and selects Cluster Manager, and then the Stabilization State performs the transfer information to Sink.

The CHEF protocol is a local cluster selection mechanism that uses fuzzy logic. CHEF identifies a number of factors that can affect network life. As such, the CHEF applies the Fuzzy Inference System (FIS)[4] to the local cluster election mechanism, which does not need to collect information from all nodes. By using fuzzy logic, computing costs are reduced and network life is extended. In addition, the operation of this mechanism is localized, the sink does not select the CH, the

sensor nodes only select the cluster head using the fuzzy logic as shown in Figure 1.

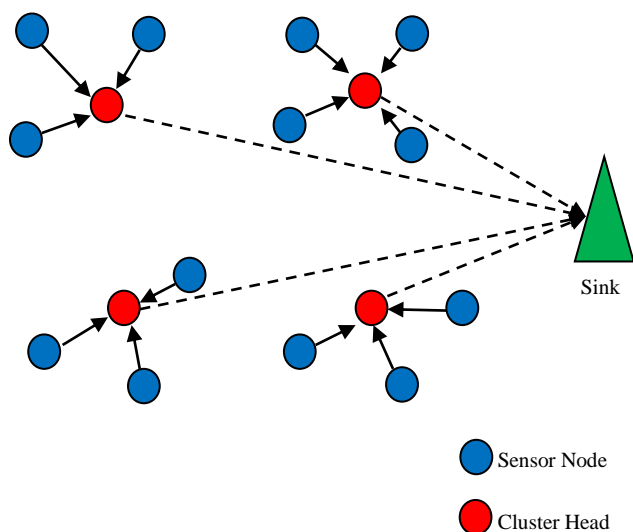


Figure 1. Network model WSN uses CHEF

Wang et al. [5] proposed an energy-efficient routing protocol where sink stations were used and randomly deployed nodes were implemented. This protocol shows good results in the energy balance of the nodes thus increasing the life span.

Taking the LEACH as a basis, due to its improvement with mobile nodes to achieve better life expectancy, was made by Nguyen et al. [6].

Xun-Xin, Yuan, and Zhang Rui-Hua in [7] proposed the use of a new energy-efficient routing using mobile station transmissions where the base station is based on the average energy of the cluster.

To discover a moving target, Yu-Chen and his colleagues [8] proposed a new protocol. In mobile, there may be a chance of losing or possibly connecting. As suggested by the protocol, nodes can efficiently restore paths and perform energy efficiency monitoring.

Communication issues among clusters in large scale networks are discussed in [9]. The authors argue that the optimization of communication between clusters head is not fully addressed in the literature and suggests a new algorithm called Broadcasting Over Cluster Head that can increase scalability and communication between the cluster.

Communication between single-hop and multihop clusters from the cluster to the base station was investigated and comparisons were made with the existing routing protocols [10].

A hierarchy-based routing support for transceiver station and node migration is proposed in [11]. It has a setup phase and a phase data forward. The sensor field is classified and each node is assigned a specific role. Most complex calculations are made in the base station. The author claims that the proposed protocol gives better energy efficiency.

A new proposal by Yim et al. [12] is a new protocol to ensure better data delivery and energy efficiency for mobile station groups. This protocol is most suitable for mobile

station base stations in applications such as war and disaster rescue areas.

In [13], the authors propose a method for routing data from a static source to a mobile station in a reliable manner, using a number of prediction techniques to predict the location of the receiving station. In terms of delay, reliability and energy efficiency, a proposal is better than conventional routing protocols.

Energy control issues are investigated in detail in [14] various active and passive methods discussed in detail with different data. It provides information on the various power control and management programs, the needs and costs of it as well as the side effects.

In order to balance energy, traditional multihop transmission is applied randomly in two phases and considers network life as an optimization problem [15]. In general, it offers three different transmission policies, which allow for extended use of wireless sensor networks.

Mobility Sink model in WSN [16] Related studies have shown that mobile-assisted routing helps reduce energy consumption to a large extent. The main reason for the sink mobility introduced in WSNs is the reduction in the number of hops required to distribute data from sensor nodes to sink. Thus, reduce delays and prolong network life by reducing the amount of energy needed to send and receive data.

Mobile sink based Energy-efficient Clustering Algorithm (MECA)[17] for wireless sensor networks, mobile sinks at the edge of the sensor area, and sink follow a fixed and predictable path. The network is divided into several clusters. CH is selected based on residual energy, each CH collects data and sends it to the mobile sink. Internal chain routing algorithms are also proposed using a multi-hop scheme.

Mobile Sink Assisted Energy Efficient Routing Algorithm (MSA) [18] focuses on the shortest hop. As the MSA uses mobile sink, the number of hop is also reduced because the mobile sink significantly reduces transmission energy. But the power level of unbalanced nodes in the network is a major factor in the loss of network connectivity. That is also the reason for the decrease in MSA performance

### III. OUR PROPOSALS

#### A. Proposal 1: Clusters combined with mobile sink

Proposal 1 provides a solution to the problem of mobile sink in hierarchical sensor networks. The mobile sink starts at a fixed location and follows a pre-planned moving path. Sensor nodes are deployed randomly in the area. Sensors are organized into clusters and CHs are selected based on the LEACH algorithm. Cluster Head have the role of collecting information from nodes in its cluster, saving data to a buffer, and then transmitting data to the mobile sink when it is in range.

Based on the MECA' algorithm idea of mobile sink model by circular, initially deployed a mobile sink at the edge around the sensor area, the sink move along clockwise (or counterclockwise) with certain velocity along the circle, its path is fixed and the motion is predicted. At each location, the sink has a certain amount of time to synthesize information from the CH. The direction of the sink counter-clockwise (or clockwise) and the velocity  $v$  of the sink are predetermined. Hence the sink just broadcasts on the network to inform all sensor nodes of its current position  $P_0$  from the beginning for

only one period. Then, when the sensor nodes record the initial position of the sink, they can change the angle  $\theta$  after an interval  $\Delta t$ :

$$v = (\theta * R) / \Delta t \Rightarrow \theta = (v * \Delta t) / R$$

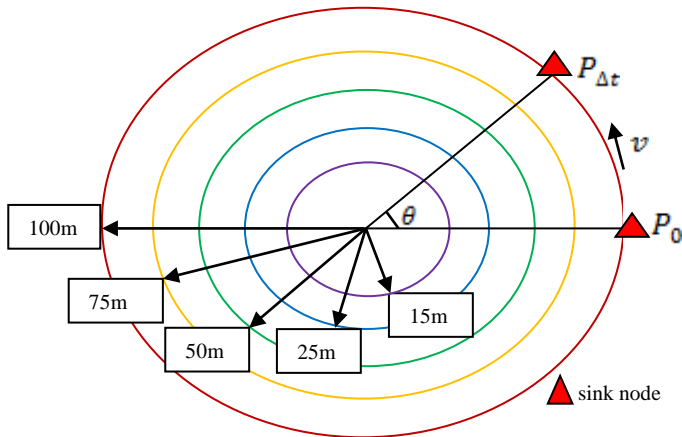
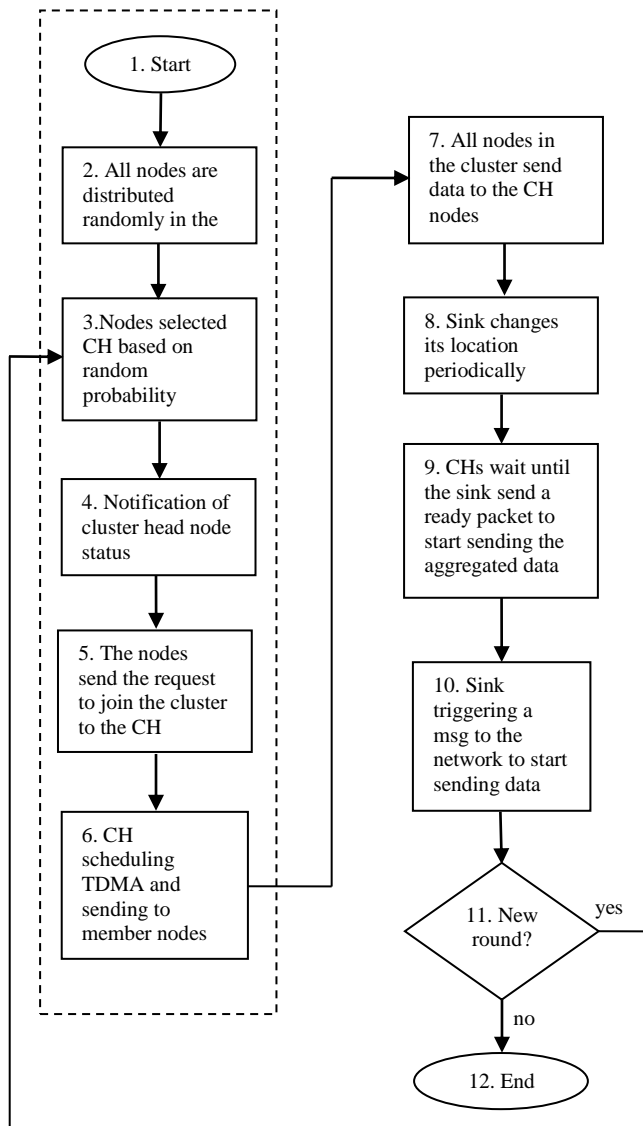


Figure 2. Mobile Sink Model of proposal Algorithm

In this paper, the sink moves in a circular orbit, with a radius calculated from the center of the sensor area  $R = 100m$  and after a period of time  $\Delta t = 40s$ , the sink changes its position once and the velocity  $V = 10m / s$ . Consider moving sink with different radius  $R$  radius corresponding to 100m, 75m, 50m, 25m, 15m for different results

The flowchart of proposed solution 1 is as follows:



The operation of Proposal 1 is divided into three phases: Network cluster phase, Mobile sink navigation phase, Data collection phase

1) **Mobile Network Cluster Phase:** The network is divided into clusters using the LEACH clustering algorithm, to become a cluster head, each node  $n$  selects a random number between 0 and 1. If this number is less than the threshold  $T(n)$ , the node will become a cluster-head for the current round. The threshold  $T(n)$  is given by the formula (2.1):

$$T(n) = \begin{cases} \frac{p}{1 - p(r \bmod (\frac{1}{p}))}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases}$$

The LEACH definition of CH is relatively random, based on the random coefficient and the energy level  $E > 0$  of the nodes. Selected clusters will advertise their neighbor nodes on the network that they are new clusters. When CH nodes are selected, they emit signals to advertise their presence within the CH's communications. Based on the received signal strength, each member node will select the CHs that they belong to. Finally, the scheduling phase is performed in which the cluster head specifies the time that the sensor nodes can send data to the cluster head based on the Time Division Multiple Access method (TDMA) and this schedule is advertised for membership nodes in the cluster. Because sensor member nodes only need low power to transmit data to CH nodes. The CH button will synthesize the data and keep it in memory and wait for the mobile sink to reach them near to collect data.

2) **Mobile Sink Navigation Phase:** In the proposed mechanism, the sink coordinate changes over time. At each position, the sink has a certain stop time to synthesize the signals from the CHs. In this paper, We give a circular motion sink, with a radius calculated from the center of the sensor area  $R = 15m, 25m, 50m, 75m, 100m$ , and after  $t = 40s$ , once and moving speed  $V = 10m / s$ .

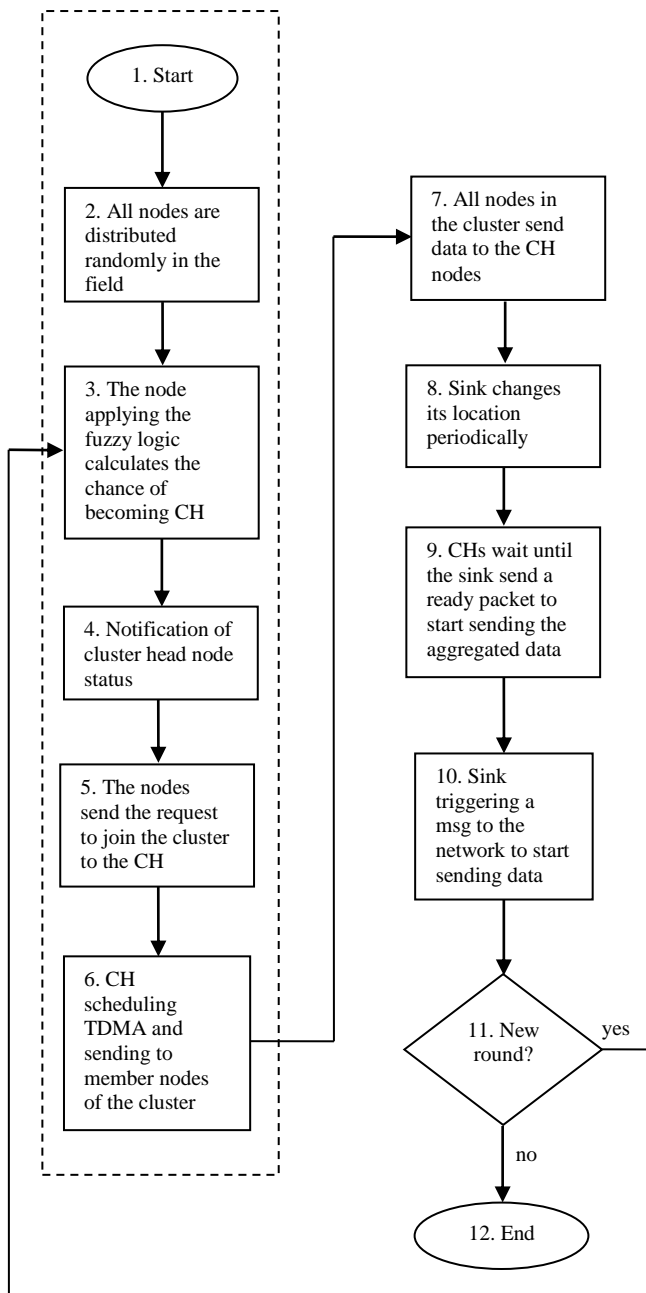
3) **Data Collection Phase:** The mobile sink when approaching the CH node, will broadcast the CH signal requiring the sending of all the stored data to the mobile sink. The CH button will forward all the aggregate data to the mobile sink. Proposed algorithm 1 with LEACH-based clustering approach combined with mobile sink can improve network lifetime better because mobile sink has reduced the transition energy consumption from CH compared to sink model permanent. However, It did not achieve the best performance due to limitations in the CH selection process based on the random probability of the LEACH algorithm. In order to overcome this limitation, it is better to select better clustering algorithm, We proposed fuzzy clustering algorithm combining mobile sink can solve this problem.

**B. Proposal 2: Fuzzy clusters combining mobile sink**

Proposed algorithm 2 offers a solution to improve the proposed algorithm 1 in better clustering selection, thereby improving the network lifetime. The cluster chief communicates with the sink. Selection of CHs was performed by using a fuzzy logic-based approach. The CHs were selected based on the two input Fuzzy Inference System (FIS) parameters: residual energy, the local distance of each node. The improvement algorithm of the second algorithm by

combining the CHEF fuzzy clustering algorithm with the circular sink model.

The flowchart of proposed solution 2 is as follows:



The operation of Proposal 2 is divided into three phases:

- The network cluster phase is based on fuzzy logic
- Mobile sink navigation phase
- Data collection phase

1) **Network clustering phase based on fuzzy logic:** CHEF configures the clusters in each loop, the sensor nodes generate a random number between 0 and 1. If the random number is less than  $P_{opt}$ , the sensor node will calculate the chance by using the fuzzy rule and then advertise a candidate message (Candidate\_Message) with chance. This message means that the sensor node is a candidate for CH with the value of opportunity.  $P_{opt}$  is defined in formula (2.2):

$$P_{opt} = \alpha \times P \quad (2.2)$$

Where  $P$  is the desired percentile rate of the cluster heads and  $\alpha$  is a constant value defining the candidate's ratio for CH. When a sensor node advertises a candidate message, this node will wait for candidate messages from other nodes. If the opportunity itself is greater than every opportunity from the other nodes, the sensor node will broadcast a CH message, meaning that the sensor node is selected as the cluster head. If a node that is not the cluster head receives the CH message, the nearest CH button is the head of the cluster and sends a message joining the cluster to the CH.

To get a chance, the CHEF uses two fuzzy sets and the if-then rule.

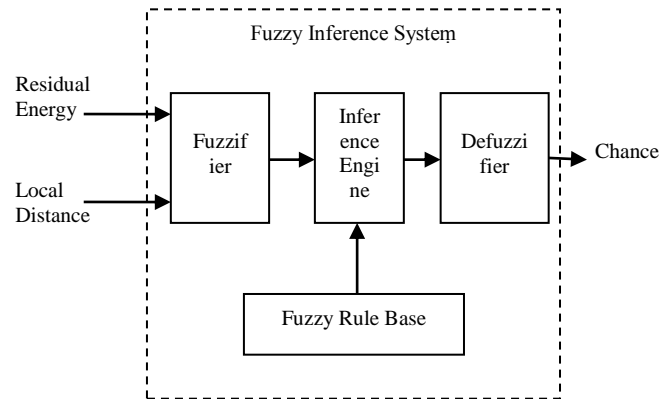


Figure 3. Cluster Head Selection Diagram based on fuzzy reasoning system

The fuzzy variables used in the if-then fuzzy rule are defined as follows:

Energy  $E_r(S_i)$  is the residual energy of the node

Local Distance  $D(S_i)$  is the sum of the distance between the node and other nodes within the radius of  $R$ .

Two fuzzy sets are defined for each input variable, where  $\mu_{E_r}$  represents the dependent function of the input energy variable,  $\mu_D$  represents the dependent function of the input variable distance.

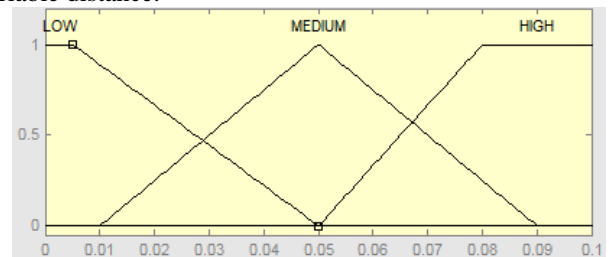


Figure 4. Energy Fuzzy Variable input FIS

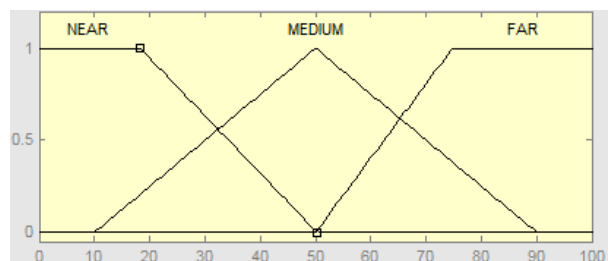


Figure 5. Distance Fuzzy Variable input FIS

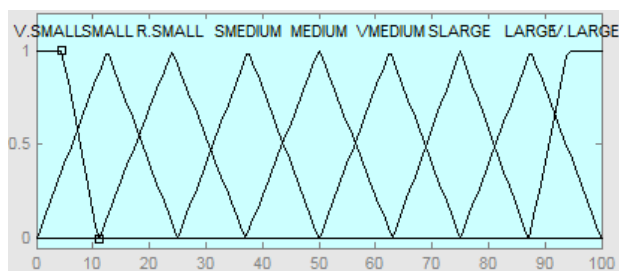


Figure 6. Output of FIS

The chance to represent the output is determined by the nine associated functions as shown in Figure 6 for most capabilities. CH is determined from time to time as the maximum probability nodes (Chance max) or nodes with  $E > 0$  and D have the smallest distance. The fuzzy rule is described in the following table:

TABLE 1. 9 FUZZYRULE IF-THEN IN PROPOSAL 2

STT	Residual Energy	Local Distance	Chance
1	LOW	FAR	V. SMALL
2	LOW	MEDIUM	R. SMALL
3	LOW	NEAR	SMALL
4	MEDIUM	FAR	S. MEDIUM
5	MEDIUM	MEDIUM	MEDIUM
6	MEDIUM	NEAR	V.MEDIUM
7	HIGH	FAR	S.LARGE
8	HIGH	MEDIUM	LARGE
9	HIGH	NEAR	V.LARGE

The CHEF mechanism overcome the drawback found in LEACH. A more energetic sensor has more opportunities to become a chief cluster because energy is considered in calculating an opportunity in fuzzy logic. In addition, local area fuzzy variables make optimal local node as a cluster head more likely. This is because the power consumption of wireless communication mainly depends on the distance between the two nodes and the density around the node will be almost the same. By considering at energy and local distances, CHEF can select the optimal CH at that time and can extend the life of the network.

**2) Mobile Sink Navigation Phase:** In proposal 2, the mobile sink is also based on the mobile sink model of the MECA algorithm, the sink coordinate changes over time. At each position, the sink has a certain stop time to synthesize the signals from the CHs. In this proposal 2, the mobile sink is circular orbit, with a radius from the center of the sensor area  $R = 50m, 15m$ , and after a period of  $t = 40s$ , the sink changes its position once and movement speed  $V = 10m / s$ .

**3) Data Collection Phase:** Similar to proposal 1, the mobile Sink once approached the CH node, which would broadcast the CH signal requiring the CH node to send all the stored data to the mobile sink. The CH node will forward all the aggregate data to the mobile sink. Proposal 2 with fuzzy clustering based on the CHEF algorithm combining mobile sink has significantly reduced energy consumption due to

better cluster selection than proposed 1 with clustering based on the LEACH algorithm combining mobile sink. This improves the life of the growing network.

To demonstrate the effectiveness of the proposed solution, algorithms are simulated, compared, evaluated results on MATLAB simulation software.

#### IV. SIMULATION RESULTS

For testing and analysis of suggestions (for power consumption), some experiments and simulation experiments were performed through Matlab simulation software. The simulation environment is set up with the parameters listed in Table 2. Assuming that all sensor nodes are randomly distributed in a  $100m \times 100m$  area, the sink hasn't energy constraint. And normal nodes have limited power. Finally, different performance indicators will be evaluated for proposals 1 and 2 and compared to the LEACH, CHEF algorithm.

TABLE 2. NETWORK PARAMETERS

Parameter Name	Value
Area simulation	$100m \times 100m$
Number of the sensor nodes (n)	100
The desired percentage becomes CH (p)	0.05
Length of the packet (k)	4000
Initial energy of the sensor nodes ( $E_0$ )	0.1
Energy consumption on circuit ( $E_{elec}$ )	50nJ/bit
Channel parameter in multi-path model ( $E_{mp}$ )	$0.0013pJ/bit/m^4$
Channel parameter in free-space model ( $E_R$ )	$10pJ/bit/m^2$
Energy data aggregation, $E_{DA}$	5 nJ/bit
Simulation time ( $t_{max}$ )	1000 round

#### For proposal 1

In the LEACH system, the BS (or sink) position is fixed, while in proposal 1, proposal 2 then BS coordinate is changed by the time. At each location, the BS has a certain stop time to synthesize signals from the CHs. In this paper, the sink moves in a circular orbit, with radius calculated from the center of the sensor area  $R = 15m, 25m, 50m, 75m, 100m$ , and after a period of time  $t = 40s$ , the sink changes position one at a time and speed Movement  $V = 10m/s$ . From the simulation results of Figure 7, we see that for each case different results are given (different alive nodes). As the sink moves toward the center of the network, the alive nodes increase. Conversely, the number of alive nodes decreases.

TABLE 3. NETWORK LIFETIME COMPARISON TABLE BETWEEN PROPOSALS 1 AND LEACH

Protocol/Time	The 1 <sup>st</sup> dead time (round)	100% dead time (round)
LEACH	121	339
Proposal 1 R=100m	112	257
Proposal 1 R=75m	125	312
Proposal 1 R=50m	124	320
Proposal 1 R=25m	124	352
Proposal 1 R=15m	131	497

- In LEACH and Proposal 1, the CH determination is based on random probability. Sink change position during simulation, when changing radius of travel  $R = 100m, 75m, 50m, 25m, 15m$ , the life of the network increases, with a radius  $R = 15m$ , the network life time longest. When the sink travels outside the sensor area with  $R = 100m, R = 75m$ , the network life decreases due to the increased data transfer

distance between the CH and the sink. When the sink travels in the sensor area with  $R = 50m$ ,  $R = 25m$ ,  $R = 15m$ , the network life increases as the data transfer distance between the CH and the sink decreases.

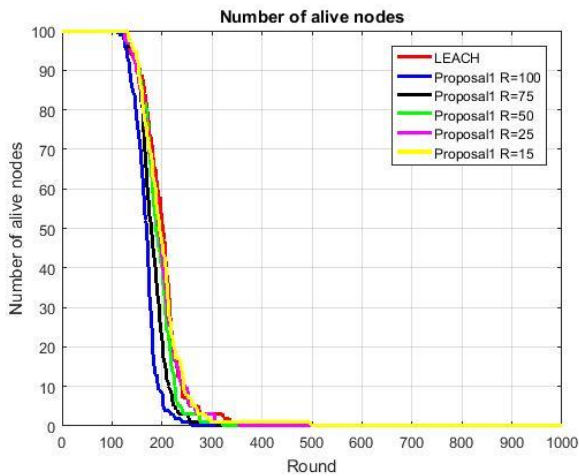


Figure 7. Comparison of alive nodes between Proposals 1 and LEACH

Figure 7 shows the comparison of alive nodes through the rounds of the simulation algorithms. The results show that better performance in reducing energy consumption is when the mobile sink, the distance between the CH and the sink decreases, the energy consumption also decreases. In the case of mobile sink, due to the sink movement, which distributes the energy dissipated between the CH nodes.

Based on the results of the simulation and Table 3, there are the following assessments:

- The number of live nodes of the LEACH mechanism is lower than the proposed 1 with  $R = 15m$ ,  $R = 25m$ .

- In proposal 1 when changing the radius of travel, the number of nodes alive and the average power of the network increases. As the sink moves closer to the center of the sensor area, the results change, but the changes are not high.

- Based on the results of Table 3 above, it is essential to improve proposal 1 by combining with other methods to increase the effectiveness of proposal 1. Therefore, proposal 2 uses fuzzy clustering combined with mobile sink to increase the effectiveness of proposal 1.

#### For Proposal 2

In Proposal 2 use fuzzy logic based on the CHEF algorithm or in other words use the fuzzy inference system (FIS) to determine the CH. The basis for using this method is based on the energy of each node and the location distance. Calculate the location distance:  $D = \sum_{k=1}^n d_k$  with  $d_k$  is the distance of the nodes in the circle of radius  $r_0$  with  $r_0$  being the maximum transmission radius of each nodes and  $n$  is the total number of nodes are in that area.

The simulation steps are as follows:

- Energy and location distance (input) functions for the fuzzy inference system (FIS).

- Establish the rules.

- Apply the fuzzy reasoning system (FIS) to calculate the probability of each node.

- Based on the probability of each node, we choose the nodes with the greatest probability to become CH.

- For sink change location during simulation, select radius  $R = 50m$ ,  $15m$ .

- The sink process collects data from the CHs in the network.

TABLE 4. NETWORK LIFETIME COMPARISON BETWEEN PROPOSAL 2 WITH LEACH, CHEF, PROPOSAL 1

Protocol/Time	The 1 <sup>st</sup> dead time (round)	100% dead time (round)
LEACH	121	339
CHEF	273	478
Proposal 1 R=15m	131	497
Proposal 2 R=50m	568	825
Proposal 2 R=15m	722	936

Based on the results of Table 4, method of Proposal 2, clustering combined mobile sink with  $R = 15m$  achieves the highest efficiency. Figure 8 shows the comparison of alive nodes through rounds of the simulation algorithms. The graph above show that the Proposal 2 are more stable than other algorithms because longer appearance of the first dead node and final dead node than the Proposal 1 and LEACH

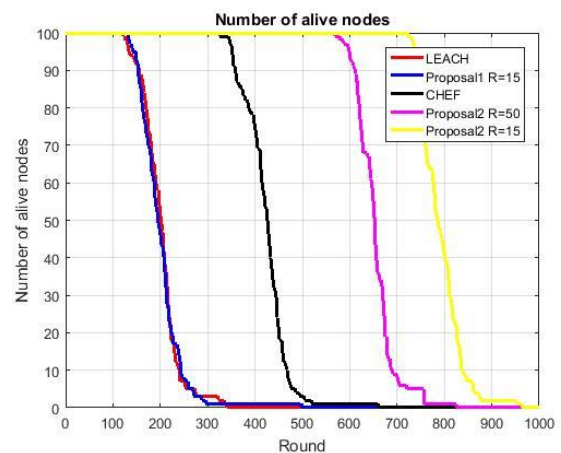


Figure 8. Comparison of alive nodes between Proposal 2 with LEACH, CHEF, Proposal 1

The results showed that the best performance in reducing energy consumption was when the mobile sink combined with clustering based on fuzzy logic, CH selection was better and the distance between CH and sink decreased, Consequently, energy consumption is reduced significantly. In the case of fuzzy clustering combined with mobile sink is higher than other protocols due to the application of fuzzy logic in the selection of CH with the CH option of other protocols and also because of the sink movement that distributes the energy dissipated between the CH nodes.

Based on the results of the simulation have commented as follows:

- Number of alive nodes and average energy of Proposal 2  $R = 15m$ , Proposal 2  $R = 50m$  higher than LEACH, CHEF, Proposal 1.

- In which Proposal 2  $R = 15m$  gives the highest result.

## V. CONCLUSIONS

In this paper we have studied the performance of using mobile sink for data collecting in WSNs. When the sink moves continuously creating good and bad performance, so choosing the model and the efficient way to mobile sink is a functional part of the proposed job. Thereby, when considering the mobile sink under different radius circles, it has shown that different network performance improves, the

closer the center of the sensor area can be to higher efficiency. Proposal 1 was an energy efficient combination based on the LEACH routing protocol developed for mobile sink was the basis for initial research. Proposal 2 was most effective when considering clustering based on fuzzy logic with the mobile sink model. The two proposals are designed, compared to LEACH, CHEF and more effective to work with homogeneous sensor environments. Both introduced proposals are enhanced with mobile sink according to predictable path for data collection mechanism, which determines the better sink motion status relative to the network life. In conclusion, the proposed combination of fuzzy clustering and mobile sink demonstrates the superiority of LEACH and CHEF protocols on network lifetime.

## REFERENCES

- [1] Muhammad Ali Khan, Arif Iqbal Umar, Babar Nazir, Noor ul Amin, Shaikat Mehmood, Kaleem Habib, "Energy Efficient Clustering Using Fixed Sink Mobility for Wireless Sensor Networks", (*IJACSA International Journal of Advanced Computer Science and Applications*, Vol. 7, No. 2, 2016
- [2] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks", in *IEEE Transactions on Wireless Communications*, 1(4), 660 – 670, 2002
- [3] Jong-Myoung Kim, Seon-Ho Park, Young-Ju Han, and Tai-Myoung Chung (2008), "CHEF: Cluster head election mechanism using fuzzy logic in wireless sensor networks", *ICACT*, 654-659, 2008
- [4] E.H. Mamdani, and S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic 98 controller", *International Journal of Man-Machine Studies*, vol. 7, issue. 1, pp. 1-13, 1975
- [5] Wang, Jin, Zhongqi Zhang, Feng Xia, Weiwei Yuan, and Sungyoung Lee, "An Energy Efficient Stable Election-Based Routing Algorithm for Wireless Sensor Networks" *Sensors*, 13, (11) 14301-14320, 2013
- [6] Nguyen, Lan Tien, Xavier Defago, Razvan Beuran, and Yoichi Shinoda, "An energy efficient routing scheme for mobile wireless sensor networks", *Wireless Communication Systems, ISWCS'08, IEEE International Symposium*, 568-572, 2008
- [7] Xun-Xin, Yuan, and Zhang Rui-Hua, "An energy-efficient mobile sink routing algorithm for wireless sensor networks" *Wireless Communications, Networking and Mobile Computing (WiCOM)*, International Conference, 1-4, 2011.
- [8] Yu-Chen, Kuo, Yeh Wen-Tien, C. H. E. N. Ching-Sung, and C. H. E. N. Ching-Wen, "A lightweight routing protocol for mobile target detection in wireless sensor networks" *IEICE transactions on communications*, 93,(12) 3591-3599, 2010
- [9] Cheng, Long, Sajal K. Das, Mario Di Francesco, Canfeng Chen, and Jian Ma, "Scalable and energy-efficient broadcasting in multi-hop cluster-based wireless sensor networks" *Communications (ICC), IEEE International Conference*, 1-5, 2011
- [10] [Arshad, Muhammad, Naufal M. Saad, Nidal Kamel, and Nasrullah Armi, "Routing strategies in hierarchical cluster based mobile wireless sensor networks", *Electrical, Control and Computer Engineering (INECCCE), International Conference*, 65-69, 2011
- [11] Sarma, Hiren Kumar Deva, Avijit Kar, and Rajib Mall, "Energy efficient routing protocol for Wireless Sensor Networks with Node and Sink mobility" *Sensors Applications Symposium (SAS), IEEE*, 239-243, 2011
- [12] Yim, Yongbin, Euisin Lee, Jeongcheol Lee, Soochang Park, and Sang-Ha Kim, "Reliable and energy-efficient routing protocol for mobile sink groups in wireless sensor networks", *Personal Indoor and Mobile Radio Communications (PIMRC), IEEE, International Symposium*, 1102-1107, 2012
- [13] Munari, Andrea, Wolfgang Schott, and Sukanya Krishnan, "Energy-efficient routing in mobile wireless sensor networks using mobility prediction", *Local Computer Networks, LCN, IEEE, Conference*, 514-521, 2009
- [14] Pantazis, Nikolaos A., and Dimitrios D. Vergados, "A survey on power control issues in wireless sensor networks", *Communications Surveys & Tutorials, IEEE*, 9, (4) 86-107, 2007
- [15] Azad, A. K. M., and Joarder Kamruzzaman (2011), "Energy-balanced transmission policies for wireless sensor networks" *Mobile Computing, IEEE Transactions*, 10, (7) 927-940, 2011
- [16] A. A. Taleb, T. Alhmiedat, O. Al-haj Hassan, N. M. Turab, "A Survey of Sink Mobility Models for Wireless Sensor Networks", *Journal of Emerging Trends in Computing and Information Sciences*, 2013.
- [17] Jin Wang, Yue Yin, Jeong-Uk Kim, Sungyoung Lee and Chin-Feng Lai, "An Mobile-sink Based Energy-efficient Clustering Algorithm for Wireless Sensor Networks", *IEEE 12th International Conference on Computer and Information Technology*, 2012
- [18] Deepa V. Jose and Dr.G. Sadashivappa, "Mobile Sink Assisted Energy Efficient Routing Algorithm for Wireless Sensor Networks", *World of Computer Science and Information Technology Journal (WCSIT), ISSN: 2221-0741*, 5, (2) 16-22, 2015



**Phan Thi The** was born in Vietnam in 1982. She received Master Data Transmission and Network in HOCHIMINH PTIT, Vietnam, 2012. She is currently a Ph.D. Candidate in Information System from Post & Telecommunications Institute of Technology, Vietnam in 2019. She is working as a lecture in Thu Duc College.



**Vu Nhu Manh** was born in Vietnam in 1984. He received B.E in Technology of University, Vietnam, 2007. He is currently a MSc. Candidate in Information System from Post & Telecommunications Institute of Technology, Vietnam in 2017. He is working as an engineer in Ho Chi Minh City Television.

**Tran Cong Hung** was born in Vietnam in 1961. He received the B.E in electronic and telecommunication engineering with first class honors from HOCHIMINH University of technology in Vietnam, 1987. He received the B.E in informatics and computer engineering from HOCHIMINH University of technology in Vietnam, 1995. He received the master of engineering degree in telecommunications engineering course from postgraduate department Hanoi University of technology in Vietnam, 1998. He received Ph.D at Hanoi University of technology in Vietnam, 2004. His main research areas are B – ISDN performance parameters and measuring methods, QoS in high speed networks, MPLS. He is, currently, Associate Professor Ph.D. of Faculty of Information Technology II, Posts and Telecoms Institute of Technology in HOCHIMINH, Vietnam.



**Dien Tam Le** was born in Vietnam in 1987. He received Master Computer science in Universite Pierre et Marie CURIE, France, 2014. He is currently a Ph.D. Candidate in Computer science and engineering from Kyung Hee University, Korea in 2020.